GUIDED BULLETS:
A DECADE OF ENABLING ADAPTIVE MATERIALS R&D

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ABSTRACT

This paper outlines a research area which is ripe for the generation of a technological surprise for the US and its allies as well as tremendous opportunity. An historical summary starting in 1995 of several disjoint US programs which were highly technically successful, but were stopped prematurely because of non-technical reasons is presented. The programs are shown to have matured critical component and subassembly technologies but were never continued far enough to be integrated into tactical rounds. The paper shows that the most critical of these technologies is related to launch-hardened flight control actuators and that work in this area continues around the world at a steady pace. The full paper concludes with a brief assessment of guided bullet flight control technology, future applications and paradigm-shifting missions.

1. MOTIVATION

The purpose of this paper is to draw attention to the emerging area of adaptive munitions in general and guided bullets in particular so as to alert decision makers to the threat coming from a likely technological surprise. Although corners of the technical community have been aware of progress in the area for some time, stop and go programs, anemic support and a lack of knowledge of adaptive munitions indicates that decision makers are not fully aware of the near-term feasibility of this technology and its long term impact. Indeed, the fact that this paper was relegated only to a two page silent synopsis is indicative of this yawning knowledge gap in the military community at large. Because enabling technologies have been in the public domain for 15 years, it is simply a matter of time till a domestic or foreign research team finally assembles a working guided bullet system.

From earlier work, it will be seen that there are several distinct subsystems in most guided hard-launched rounds. It is clear that the most challenging among them is flight control. It was shown earlier that all other subsystems can be constructed from commercially available components with little or no changes. The flight control system, however, is different. Because of the extreme conditions, deflection, force, moment, power consumption and bandwidth requirements, only a handful of actuator classes can satisfy all requirements. From Ref. 1, it can be seen that the most daunting of these requirements can be succinctly bracketed:

Table 1 Challenging Design Drivers for Guided Bullets[1]

Setback Acceleration	5,000 –100,000g's
Setforward Acceleration	1,000 – 5,000g's
Balloting	1,000 – 5,000g's
Rotational Acceleration	100k – 1M rad/s^2
Storage Temperature Range	*-40°C to +63°C*
Operational Temperature Range	*-9°C to +63°C*
Controlled Storage Life	20 years
Uncontrolled Storage Life	1 – 10 years

From Ref.'s 1 - 6, it can be seen that other design drivers like muzzle velocity, range, impact energy, caliber, maneuver margin, gust insensitivity, inclement weather resistance, target tracking, intercept profile and bandwidth are specific to each individual mission and type of round. Given a wide range of missions, it is impossible to list all in this abbreviated space.

2. HISTORICAL OVERVIEW

Over the past decade, quite a number of adaptive munition, guided bullet and cannon shell programs have been conducted from 5.56mm to 40mm in caliber for missions supporting Army snipers to aerial gunnery.

2.1 Barrel-Launched Adaptive Munition (BLAM '95 -97)

This first adaptive munitions program was started in May of 1995 at the USAF Armament Directorate, Eglin AFB, FL.

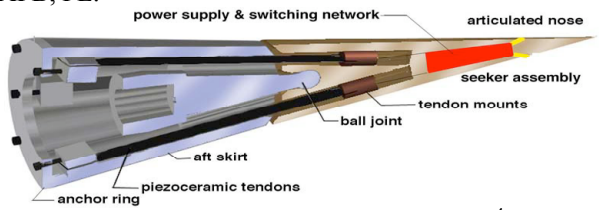

Fig. 1 BLAM Internal Arrangement[4]

The overall mission was to increase the hit probability and probability of a kill given a hit for close-in and medium-range air-to-air engagements for all threats including all classes of aircraft and missiles. The program lead to the development of manufacturing techniques which could be used to harden otherwise fragile piezoelectric actuators so that they would be able to withstand setback loads. Experimental tests were conducted on a 10° half-angle 37mm cal. articulated conical projectile. A series of specimens were built and tested statically and dynamically on the bench and on the 213m long Eglin AFB, BEF range.

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Extensive wind tunnel testing was conducted at Mach 3.3, demonstrating good maneuverability and flight control system bandwidth through 200 Hz.

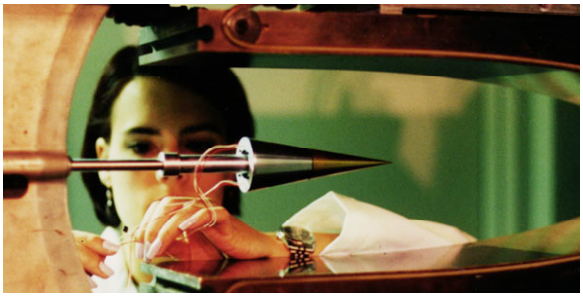

Figure 1 BLAM Test Article in Supersonic Tunnel

The technical success of the BLAM program was profound and lead to many reports and open publications including Ref. 3 and 4. Although highly successful from scientific, military and engineering standpoints, the program was terminated.[5]

2.2 Range-Extended Adaptive Munition (REAM '98-99)

With the demise of the BLAM program, the REAM effort began anew to support the Army sniper mission. A series of 0.50 cal. rounds were designed, built, bench and wind tunnel tested. The program concluded successfully with all technical goals being exceeded.[6]

2.3 Spike-Controlled Adaptive Round (SCAR '00)

The SCAR program was proposed to DARPA TTO and later ATO as a low control authority mechanism for guiding supersonic projectiles.[7] Although funding was declined for the original proposing team, the concept was re-initiated and another institute was funded.[8]

2.4 Light Fighter Lethality Adaptive Round (LFLAR '01-02)

By using the best of the technologies developed in the REAM program, the LFLAR effort was conducted to demonstrate the utility of the adaptive flight control mechanisms on subsonic rounds.[9]

2.5 Hypervelocity Interceptor Test Technology (HITT '98-00)

In an effort to bring the benefits of adaptive actuators to hypersonic vehicles, a set of piezoelectric actuators were designed, built, integrated and tested in a hypersonic interceptor. The actuators proved to be the quickest fully proportional flight control mechanisms ever built – working against full airloads in under a few miliseconds.[10]

2.6 Shipborne-Countermeasure Range-Extended Adaptive Munition (SCREAM '01-03)

This Phase II SBIR continuation to the REAM program, was focused on defending ships from highly maneuverable sea-skimming missiles. It was shown that high authority actuators could be built to withstand several tens of thousands of g's of setback accelerations while providing high speed, high authority flight control for small caliber cannon shells and bullets.

3. ASSESSMENT OF GLOBAL GUIDED BULLET DEVELOPMENT CAPABILITIES

Technologists around the world are gaining an ever more acute understanding of the design principles behind guided bullet flight control actuators by applying basic structural mechanics and aerospace design principles. Because the design of low performance actuators is simple, it is likely that such guided bullets will appear on the open market in the near term. It should also be noted that it is likely that the newest actuator classes far outperform all those previously mentioned in control authority, force, deflection generation and robustness with many of them currently undergoing development outside of the US.

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CONCLUSIONS

It can be concluded that guided bullet programs in the US have matured critical supporting technologies. However, stop-and-go funding has hampered their maturation into tactical, fielded guided bullet systems. Given the dynamic nature of other guided bullet programs around the world it is highly likely that the US will be technologically surprised by the appearance of such systems in the not-so-distant future.